

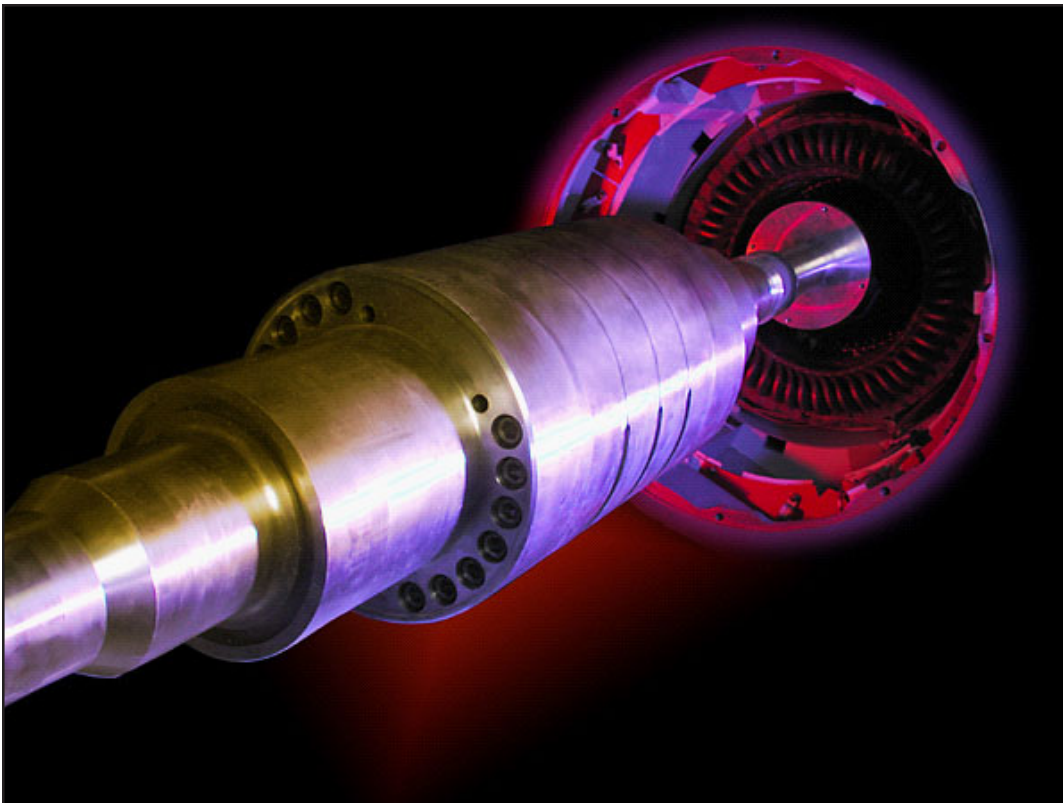
GENERATOR

P R O J E C T • F A C T • S H E E T

SPI PROJECTS ARE CO-FUNDED BY THE U.S. DEPARTMENT OF ENERGY
SUPERCONDUCTIVITY FOR ELECTRIC SYSTEMS PROGRAM AND INDUSTRY PARTNERS



**Superconductivity
Partnership with Industry**



Rotor assembly for the 1.5 MVA HTS generator prototype. (GE Global Research Center)

WHAT ARE ITS PRIMARY APPLICATIONS?

Large generators are typically installed at power generation plants. High Temperature Superconductivity (HTS) generators have the potential to improve efficiency in new power plants as well as through the retrofitting of existing plants.

WHAT ARE THE BENEFITS TO UTILITIES?

The major benefit of the adaptation of HTS generators into power plants is increased system efficiency. Generators lose power in the rotor windings and in the armature bars. By using superconducting wire for the field windings, these losses can be practically eliminated. The

fields created in the armature by the HTS rotor are not limited by the saturation characteristics of iron. Unlike conventional generators, the armatures are constructed without iron teeth. This removes the field losses usually created by the armature "teeth." The added space for copper in the armature made possible by the removal of the armature teeth further reduces losses.

HTS generators will produce electric power with lower losses than their conventional equivalents. GE expects the HTS generator to achieve a 0.35 to 0.55 percent efficiency gain over a copper winding generator. A 1,000 megawatt (MW) superconducting generator (a

typical size in large power plants) could save as much as five MW per year in reduced losses per generator. In the power generation industry, even small efficiency improvements produce big dollar savings. A half of one percent improvement in generation efficiency provides a utility or independent power producer with additional capacity to sell with a related value of nearly \$200,000 per 100 MVA generator, assuming electricity prices of 5¢/kWh and 8,000 operating hours per year.

An HTS generator will also be smaller and lighter, about 1/3 the overall volume of its conventional equivalent. In power plants where expansion is difficult (for example on ships or locomotives), super-

GOAL:

Develop and fully test under load a 100 MVA prototype generator.

TEAM:

GE Corporate Research and Development (team leader)

GE Power Generation Technology (generator technology)

PG&E (site selection)

American Electric Power (technology evaluation)

American Superconductor (HTS wire)

Sumitomo (refrigeration)

NYSERDA (additional funding)

Oak Ridge National Laboratory (related studies)

Los Alamos National Laboratory (related studies)

National High Magnetic Field Laboratory (conductor life studies)

PERIOD OF PERFORMANCE:

2002 - 2006

CUMULATIVE PROJECT FUNDING:

Private \$14.4 million (54%)

DOE \$12.3 million (46%)

Total \$26.7 million

WHAT IS IT?

Generators convert mechanical energy into electrical energy. This project will develop a generator that uses high temperature superconducting windings, which will increase the unit's efficiency and reduce its size.



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Generator windings made from High Temperature Superconducting tapes as part of an earlier DOE/GE partnership. (GE Global Research Center)

conducting generators could increase generating capacity without using additional space. Smaller, lighter HTS generators use an "air core" design, eliminating much of the structural and magnetic steel of a conventional equivalent. Construction, shipping, and installation are all simplified and less costly as a result of the smaller dimensions and lighter weight.

Another major benefit of HTS generators is lowered armature reactances. This benefit can profoundly impact utility transmission and distribution stability considerations. One implication is a reduction in the amount of spinning reserve (unused but rotating generating capacity) needed to insure a stable overall power system. Another benefit is that a HTS generator has the capability of

being significantly overexcited to permit power factor correction without adding synchronous reactors or capacitors to the power system. This improved system stability could result in improvements in reliability.

WHAT IS THE MARKET POTENTIAL?

Generators represent a large, established worldwide market. The U.S. Energy Information Adminis-

tration estimates that demand for new generation in the USA between today and 2025 will be 428 gigawatts (GW), or over 4,000 units the size of the generator that will result from this project. Additionally, hundreds of gigawatts of existing generators will face replacement in the next two decades.

The worldwide market is expected to be even larger. Forecasters predict electricity demand to nearly double by the year 2020, with new generation facilities coming on-line in virtually every corner of the globe.

WHAT ARE THE PROJECT ACCOMPLISHMENTS TO DATE?

The current project was awarded in mid 2002. Initial efforts are focusing on building and testing

a 1.5 MVA demonstration machine, and a rotor for this device has been constructed and is undergoing testing. Following the laboratory testing of the 1.5 MVA unit testing, the team will begin constructing a HTS rotor for a full scale generator. The 100 MVA rotor will be installed in a conventional generator and fully tested under load. In addition to the 100 MVA demonstration generator, GE will develop designs for generators as large as 250 MVA based on the knowledge gained in this project.

GE and DOE originally formed a partnership to investigate HTS generators in 1993, and sample generator windings were produced (see picture). Conceptual designs for larger HTS generators were also developed, and are contributing to the 100 MVA design.

The new project will utilize knowledge gained from earlier superconducting generator projects, but will differ in several important ways. GE expects to use the same stator core and winding design. The frame, as well, will not be altered, so that the unit's geometry is compatible with turbines and other power

plant equipment for retrofit applications. However, the new project will involve a new cryogenic refrigeration system, cryogen transfer coupling, and rotor coil and support scheme. The unit will have a rotor diameter of up to a meter, and at that size the support structure must be able to withstand centripetal forces on the surface of the rotor of up to 10,000 g. GE has also stressed demonstrating HTS generator technology that will meet or exceed the established generator industry performance of one percent unavailability.

How Does it Work?

A generator converts rotational mechanical input energy, such as that from a steam or gas turbine, into electricity. It does this by rotating a rotor field, which produces voltage in stationary armature conductors. The generator field can be produced with copper windings or permanent magnets. In large machines, mechanical considerations and the desire to vary the level of field produced typically favor the use of copper windings over permanent magnets.

WHAT IS THE STATUS OF THE PROJECT?

This partnership was awarded in late 2002. Initial efforts are focusing on building and testing a 1.5 MVA demonstration machine, and a rotor for this device has been constructed and is undergoing testing. Conceptual designs for the 100 MVA generator are underway.